

Attachment 1: Description of Emission Reduction Measure Form

Please fill out one form for each emission reduction measure. See instructions in Attachment 2.

Title: Emission Reduction by Direct Photoelectrochemical Hydrogen Generation and Energy Generation by Hydrogen Fuel Cell Employing no Fossil Fuel or Utility Electricity

Type of Measure (check all that apply):

- | | |
|--|--|
| <input type="checkbox"/> Direct Regulation | <input type="checkbox"/> Market-Based Compliance |
| <input type="checkbox"/> Monetary Incentive | <input type="checkbox"/> Non-Monetary Incentive |
| <input type="checkbox"/> Voluntary | <input checked="" type="checkbox"/> Alternative Compliance Mechanism |
| <input checked="" type="checkbox"/> Other Describe: Energy Available Without Carbon Based Fossil Fuel | |

Responsible Agency: ARB

Sector:

- | | |
|--|--|
| <input checked="" type="checkbox"/> Transportation | <input checked="" type="checkbox"/> Electricity Generation |
| <input checked="" type="checkbox"/> Other Industrial | <input type="checkbox"/> Refineries |
| <input checked="" type="checkbox"/> Agriculture | <input type="checkbox"/> Cement |
| <input type="checkbox"/> Sequestration | <input checked="" type="checkbox"/> Other Describe: Renewable Energy Generation |

2020 Baseline Emissions Assumed (MMT CO₂E): Where the proposed photoelectrochemical hydrogen generation program is not introduced all of the assumed 2020 baseline emissions in million metric tons of carbon dioxide equivalents (MMT CO₂E) would occur.

Percent Reduction in 2020: Expect 50% reduction in 2020 baseline emissions where 50% of even the 200 hydrogen highway fillings stations employ direct photoelectrochemical hydrogen generation instead of natural gas is now being done. Where all 200 hydrogen stations generate their fuel on-site using direct photoelectrochemical system 100% of the emission reductions would be achieved.

Cost-Effectiveness (\$/metric ton CO₂E) in 2020: Discussion of Project Compliance with Latest CARB Standards

The proposed project leads to an operating product that is in compliance with the latest CARB standards, including 2007 standards, yielding numbers that are even lower than the compliance standards.

The following Exhibit shows the air emissions of major generating pollutants per MWh. For solar, wind, hydro, and nuclear there are no NO_x, SO₂, CO₂ or particulates by pounds per mega watts per hour. Since the PHG hydrogen generating system proposed in the present demonstration project employs only solar sources for splitting water, none of the above noted pollutants are expected to be emitted from an operating system.

The publication *Fuel From the sky: Solar Power's Potential For Western Energy Supply*, Page 98 provides the following quotation that references solar energy impact that does not employ natural fossil fuels, including natural gas: "Solar power plants, at least the ones that do not use hybridization with fossil fuel for off-sun generating during cloud cover or at night, produce no air emissions." It is noted that the solar generator at Kramer Junction, CA uses natural gas if they need to keep up on the required quota of electricity. Therefore that system is not entirely free of natural gas.

The proposed PHG system is a specific improvement over use of natural gas as fuel. Natural gas is proposed for use in some vehicles. For example, traditional motor vehicles are the single largest source of major criteria air pollutants and produce more than 60% of all carbon monoxide pollution. Natural gas contains less carbon than any other fossil fuel therefore using natural gas reduces, but does not eliminate exhaust emissions of: Carbon monoxide by 70%, non-Methane Organic Gas by 87%, Nitrogen Oxides by 87% and Carbon Dioxide by 20%. As such, natural gas vehicles are inherently cleaner than traditional motor vehicles. Some, like the Honda GX, even meet California strict ultra-low and super ultra-low emission standards. However, the Honda FCX, using hydrogen as fuel will only produce water and no other contaminants, thus exceeding California pollution regulations.

Description: Description of Proposed Technologies

- What is the innovative renewable technology? How does it work?

The process is identified as: Direct Photoelectrochemical Hydrogen Generation.

Photovoltaic solar cells are encapsulated with an electrolyte, and solar exposure passes through a curved glass concentrator and the electrolyte for up to 6 suns solar concentration. This on-site generated solid-state solar cell electricity is sent to a (+) anode and a (-) cathode separated by a membrane. Electricity is also generated by low wind turbines and fed into the case as opportunity is available. Water is split into completely separated hydrogen on the cathode side and oxygen on the anode side of the membrane. The hydrogen, in this instance is piped off for burning in a boiler or into storage for later use. Such hydrogen may also be employed in fuel cells for electricity or for fuel in gas type refrigeration, furnaces or ovens in residential, commercial, industrial and government and military uses, including for all types of vehicle power. This system does not employ the traditional electrolyzer and incumbent utility or diesel generated

electricity. This technology has been the subject of investigation at the National Renewable Energy Laboratory (NREL) in Denver, CO and the present proposal is an effort to bring this technology out of the laboratory and make it useful as a replacement for natural gas with a future for the public, commercial, and industrial markets.

- How does it differ from commercially available technology?

This solar hydrogen generation process using on-site sunlight, low wind, and a base of water does not need nor use any fossil fuels such as oil, natural gas, coal or utility electricity. It employs only concentrated solar and wind energy to split water to derive hydrogen. It uses no traditional electrolyzer. There are many large government sponsored efforts to reform natural gas to derive hydrogen, but those efforts keep the system tied to the long distance pipe lines and associated deep gas and oil wells. The only new electrical generating plant in California is fired by natural gas that is largely imported on ships from foreign countries.

Emission Reduction Calculations and Assumptions:

Cost-Effectiveness Calculation and Assumptions: Expect 12.4% efficiency solar-to-hydrogen generation using only solar - no fossil fuel. This system employs only solar energy and this efficiency is very different than photovoltaic cells that report various efficiencies from 8% to 34%. This proposed system is direct sun light to hydrogen not just to photo voltaic electricity.

Implementation Barriers and Ways to Overcome Them: Main barrier is lack of understanding and appreciation that this on-site renewable energy source will replace the use of natural gas and other fossil fuels. The basis is that only 1.3 VDC is required to split water into hydrogen and oxygen and that is difficult for people to perceive the value of the system. Further research and development and education can overcome this.

Potential Impact on Criteria and Toxic Pollutants: When the present photoelectrochemical hydrogen generator is employed using solar energy to split water no pollutants such as NOx, VOC, PM10, PM2.5 or toxic air contaminants such as diesel particles or benzene are emitted. Where fuel cells are employed to generate electricity no pollutants are yielded. Should hydrogen be burned in internal combustion engines very little particulates are emitted.

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